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# STEAM STERILIZATION OF SOIL

## for Tobacco and other Crops

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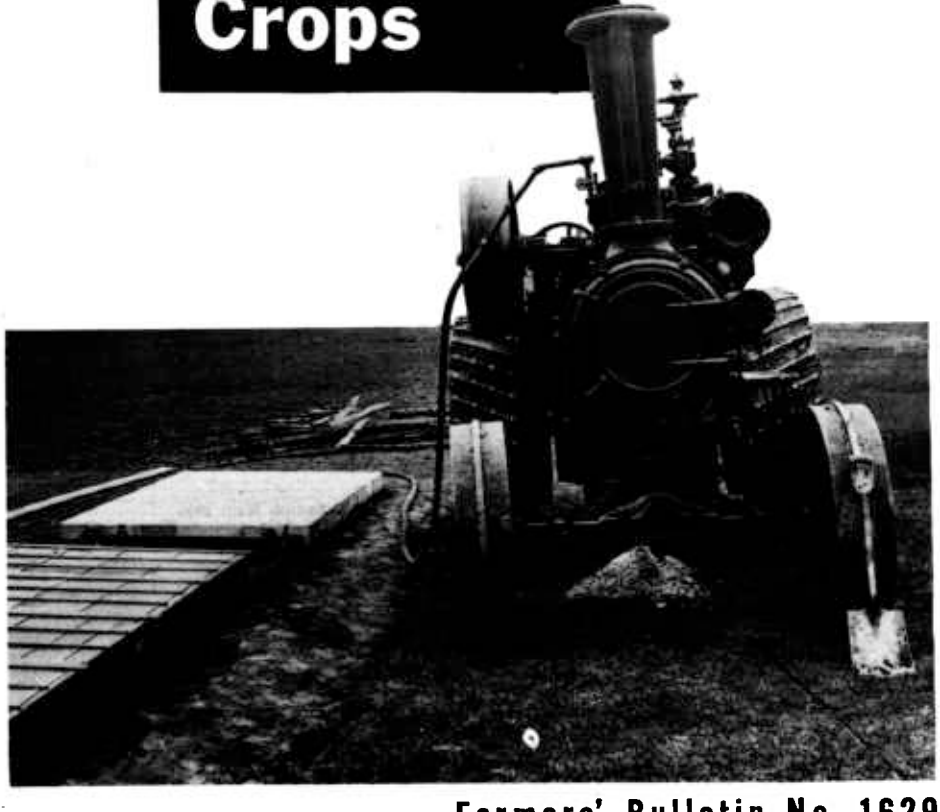

Farmers' Bulletin No. 1629
U. S. DEPARTMENT OF AGRICULTURE

SOIL STERILIZATION is being generally adopted for the production of tobacco and other seedlings in plant beds and for the culture of certain plants in glass houses. The inverted steam-pan method is the most common and satisfactory method of performing this operation in out-of-door seedbeds.

The marked benefits secured from soil sterilization are due largely to the destruction of plant diseases, insects, and weed seeds narbored in the soil and to the increased soil fertility which usually accompanies the treatment.

This bulletin describes the equipment necessary for soil sterilization by the steam-pan and other methods. Advice is also given relative to the details of preparing the soil, performing the work, and the subsequent management of the sterilized soil. Modifications to suit special needs and requirements are also suggested.

This bulletin supersedes Farmers' Bulletin 996, Steam Sterilization of Seed Beds for Tobacco and Other Crops.

Washington, D. C.

Issued May 1930
Slightly revised August 1937

# STEAM STERILIZATION OF SOIL FOR TOBACCO AND OTHER CROPS [1]

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## INTRODUCTION

THE PRODUCTION of early, vigorous, and healthy seedling plants of tobacco and other crops is one of the most important steps in their successful cultivation. The sterilization of soil by steam is of great aid in the production of desirable plants. The practice of soil sterilization has become very general in recent years in tobacco and in vegetable forcing-house districts, though the idea is by no means a new one. The beneficial effects of heated soils on plant growth were recognized by the ancients, and methods of burning over the surface soil for certain crops have been practiced for centuries. With the modern development of agriculture on a more intensive scale and along more scientific lines, new and definite reasons for soil sterilization became evident, and, consequently, improved methods of sterilization have been sought. Various types of heat and chemical treatments for this purpose have been tested, but as yet none has proved as efficient and reliable as sterilization by steam.

The principal purposes of soil sterilization are concerned with the destruction of soil-borne plant diseases, weed seeds, and in some cases soil-hibernating insects, and at the same time sterilization ordinarily has the effect of increasing soil fertility and producing conditions in general more favorable to the rate and uniformity of plant growth.

While the beneficial action of steam sterilization on plant growth is usually very striking, it should be more generally understood that a temporary injurious effect on seed germination and early plant growth usually precedes the beneficial effect. It is also important to remember that improper sterilization and poor management of the

[1] Additional information on soil sterilization is given in U. S. Department of Agriculture Technical Bulletin 443.

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soil after treatment may yield unsatisfactory results. When good judgment is used in applying the treatment, steam sterilization will be found to be an increasingly profitable practice for the culture of tobacco and vegetables, as well as for numerous other plants.

## EFFECTS OF STERILIZING THE SOIL

### SOIL-BORNE DISEASES DESTROYED

A large number of the most injurious diseases of plants are harbored in the soil. Some of these diseases are particularly destructive to germinating seeds and young seedlings. Others may cause little or no actual injury in the seedbed, merely infecting the plant in the seedling stage but producing damage in the field later in the season or in following seasons as a result of the dissemination of the pest throughout the fields during transplanting.

The following diseases of tobacco may be wholly or partially harbored in or on the soil: Damping-off or bed rot, black root rot, root knot, black shank, sore shin, mosaic, wildfire, and black fire. In addition, brown root rot, a malady of uncertain nature but associated with the effect of preceding crops grown on the land, may be obviated by steam treatment of the soil.

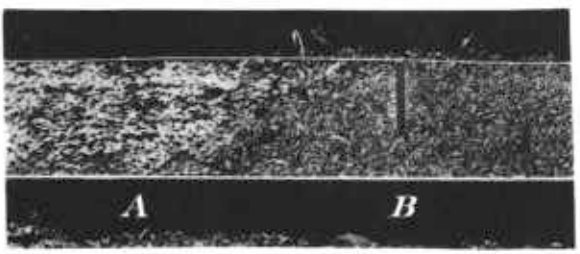


FIGURE 1.—One of the most conspicuous advantages of steam sterilization of soil is the destruction of weed seeds: *A*, Steam sterilized tobacco seed bed; *B*, not sterilized.

Similar soil-borne diseases affect various other seedlings from those of orchids to forest trees. The only available method for the destruction of the bacteria, fungi, or other infectious disease-producing agencies carried in the soil is sterilization of the soil by means of heat or chemicals. Some of these diseases, however, may be avoided by a change of soil or by the use of disease-resistant varieties, but even in such cases soil sterilization for other purposes is desirable.

### SOIL-HIBERNATING INSECTS AND OTHER PESTS DESTROYED

Insects and other forms of animal life living or being harbored in the soil in certain stages of their life are, of course, killed by the steaming of the soil.

For the control of pests which may migrate to the seedbeds from other locations after the steaming has been performed, such as springtails, flea beetles, grubs, aphids, the red spider, and slugs, consult the Bureau of Entomology and Plant Quarantine of this Department or write for farmers' bulletins relating to the control of tobacco pests.

### DESTRUCTION OF WEED SEEDS

Most plant growers who have used the steaming method find that it pays from the weed-killing standpoint alone (fig. 1). The weeding by hand of even comparatively small seedbed areas is fre-

quently tedious and expensive, coming as it does during the spring rush of work, whereas the destruction of weed seeds by steaming is rapid and efficient. In order to kill all the weed seeds, however, the steaming must be properly done. If the soil is steamed when too compact or moist, or for too short a time, many of the weed seeds may escape. This is especially true of certain seeds such as clover, which are somewhat resistant to heat as compared with other seeds.

### INCREASE IN SOIL FERTILITY

A common beneficial effect of steaming the soil is the increased rate of plant growth eventually obtained. This is largely on account of the increased fertility of the soil brought about by conversion of unavailable forms of nitrogen into available forms as a result of the heat and of changes in the type of soil organisms predominating, of which some are injurious and others are beneficial to the liberation of plant food. In soils naturally low in plant-food elements, especially in very sandy soils, steaming may be of little or no benefit in this respect.

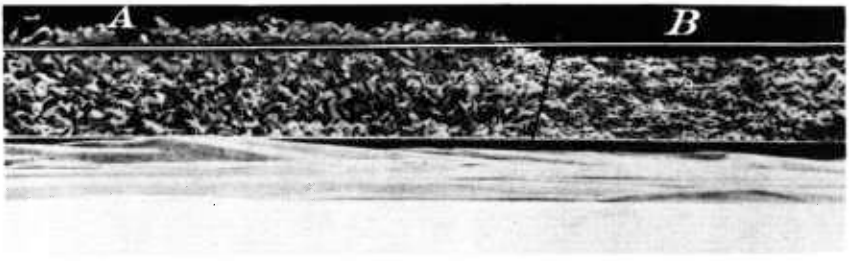


FIGURE 2.—Stimulating effect of steaming the soil on growth of tobacco seedlings: A, Tobacco on steam-sterilized soil; B, tobacco on unsterilized soil.

The increase in growth of plants on certain steamed soils is often remarkable (fig. 2). Steamed soil may frequently produce early, vigorous, and uniform tobacco plants, while unsteamed soil immediately adjoining may fail completely to produce satisfactory plants in time for transplanting.

### INJURIOUS EFFECTS OF SOIL STERILIZATION

Temporary retardation of seed germination and of early plant growth is characteristic of heat-sterilized soil as compared with unsterilized soil. This effect may last such a short time as to be hardly noticeable or may be manifest for some weeks. The plants ordinarily recover rapidly, however, and the beneficial effects of the steaming soon overcome the early setback. The temporary toxic effect appears to develop as a consequence of an overproduction of ammonia in the soil. When the ammonia becomes absorbed or changed to nitrates, it serves as a plant food, resulting in an increased rate of growth of the plants. The amount of injurious and beneficial action on plant growth varies with the soil type, the temperature of heating, the length of heating, the species of plant grown in the soil, and other factors. With our present knowledge of the subject, it is impossible to predict the extent of the injurious or beneficial action that is likely to result in any particular soil.

Another type of injurious action in steamed soils is that due to disturbed water relations. For some time after steaming, the soil may not take up or hold water readily. Consequently, steamed soils dry out rapidly, with resulting danger to very young seedlings if not watered judiciously during dry, hot weather. This condition is also temporary and is more marked in some soils than others. Naturally, these temporary injurious effects may be largely overcome by steaming some time prior to seeding or planting.

## METHODS OF STERILIZING SOIL

There are two principal ways in which soil may be sterilized, namely, by heat and by chemicals.

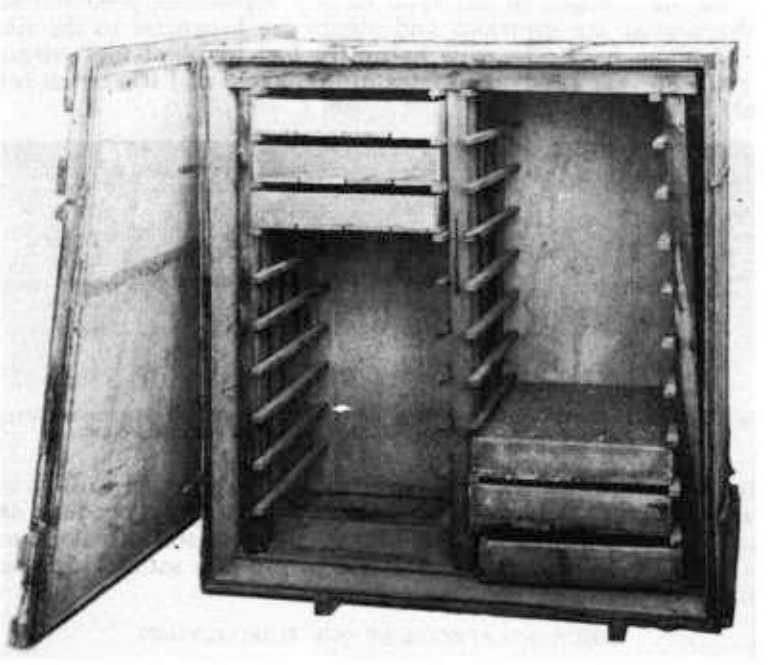

FIGURE 3.—Device for steaming soil in greenhouse flats. When only small quantities of soil are to be sterilized, a simple chamber of this sort may be constructed cheaply.

Various methods of sterilization by heat have been developed and practiced at different times. The old surface-firing method consists simply in burning brush or logs on the ground to be sown and depends largely for its sterilizing action on the conversion of the soil moisture to hot water or steam. If it is carried too far the soil may be "burned" and certain of its physical and chemical properties injured. The first modification of this method was essentially a roasting process, the soil being placed on supported sheet iron and a fire placed below. A patented tobacco plant-bed furnace for more convenient roasting of the soil may be secured on the market. Both the surface-firing and the roasting methods are used to a considerable extent in southern tobacco-growing sections, especially where wood is plentiful and steam boilers are scarce.

Boiler-generated steam was first used to sterilize soil for greenhouse seedlings by installing a perforated steam pipe in a box in which the soil was placed for heating. With various types of improvement in the construction of the sterilizing box or chamber, this method is frequently used in greenhouse practice (fig. 3). For sterilizing large quantities of greenhouse bed soil with less handling, horizontal grids of perforated pipe or tile systems are buried about 8 to 12 inches below the soil surface, for the uniform distribution of steam in the soil. Still another modification of this principle is the harrow type of sterilizer in which short vertical perforated pipes set on a grid of steam pipes are forced into the soil from the surface. This involves still less handling of the soil than in the case of the

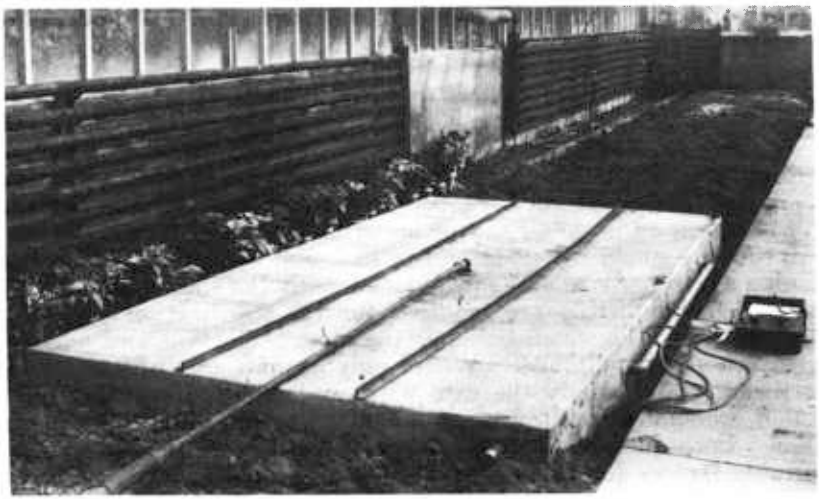

FIGURE 4.—The inverted pan used for steaming the soil. The instrument shown to the right was being used experimentally for the measurement of the temperature of the soil at various depths during and following steaming.

removable perforated-pipe system. Neither the perforated pipe nor the harrow system has come into general use on account of certain disadvantages. The permanent tile system has some advantages in greenhouse-soil sterilization and is being tested outdoors.

The big improvement in methods of sterilization came with the development of the inverted steam-pan method, which possesses many advantages in convenience and efficiency over the earlier methods, especially for out-of-door seedbeds. In principle this procedure consists simply in placing a large pan over the soil in an inverted position and running steam under the pan, thus confining the steam near the soil surface and forcing it into the soil beneath (fig. 4). This is the method now generally recommended for tobacco growers and widely used by them for seedbed sterilization. It is also frequently used in the production of other seedlings and for greenhouse vegetable culture.

Another method of heat treatment of soil that has received some consideration in recent years is sterilization by the use of hot water. This method may be useful in special instances, but so far as known it has not been practical except on a small scale.

A great deal of investigational work has been carried on in an attempt to find a suitable chemical for soil-sterilization purposes. Several difficulties lie in the way of much progress in this direction, and until a cheap, rapidly volatilizing chemical is found which can be applied to the soil in the dry state and which is as efficient as heat in sterilization, it is not probable that the latter will be displaced.

Of the large number of substances tried, formaldehyde is the only one that has been frequently used. The cost of its use is, however, about as great as that of steaming and the results are usually less satisfactory. Drenching the soil with formalin at the rate of 1 part to 50 parts of water is useful in certain instances where the control of fungus infestation of the soil is of major importance. The formaldehyde-dust method is a modification of this treatment. Acetic acid, copper, and zinc compounds have proved successful for disinfection in some instances.

## THE INVERTED-PAN METHOD OF STEAMING THE SOIL

### EQUIPMENT NECESSARY

Since the steam-pan method is the most practical one for the steam sterilization of soil for tobacco seedbeds, it is the only one that will be discussed in detail in this bulletin.

A suitable steam boiler, steaming pan, and connecting steam hose or pipe of proper size and convenient length (as shown on the title-page of this bulletin) are required for the sterilization of soil by this method. The steam boiler is the most important and most expensive item of equipment. Where only a small area of soil is to be sterilized, as is usually the case with seedbeds, individual growers cannot economically purchase or maintain a boiler for this purpose alone. Consequently, it is the usual practice for persons owning portable boilers for other purposes to supply themselves with the remainder of the necessary equipment for soil steaming and to perform this work for the growers in the community at an agreed price for a given area. In grain-growing regions suitable steam boilers used in threshing outfits are usually available for this purpose, but with the increasing tendency to use oil and gas power a scarcity of steam boilers is evident in certain regions. This is especially true in seasons in which weather conditions are unfavorable for steaming and the time available for the work is consequently short. It seems likely, therefore, that in the near future a moderately priced special boiler, mounted on a suitable truck, will need to be developed to replace the steam tractors now in use (fig. 5). Other smaller and more easily portable steam generators (propelled by gas motors) are also being developed for this purpose. Sterilization of soil in greenhouses is usually simplified in this respect in that the steam-heating plant may be used, but even in this case boilers of sufficient capacity and capable of carrying a sufficient pressure must be available.

The boiler must in the first place be of sufficient capacity to supply the required quantity of steam for the size of pan used. In general, the greater the steam capacity of the boiler the larger the area that can be steamed at one time. A boiler of at least 20-horsepower capacity is necessary for a steam pan 72 square feet in area. A 30

or 40 horsepower boiler is usually even more desirable for this size of pan, since the desired steam pressure is more readily maintained.

The steam pressure in the boiler should be maintained above 80 pounds during steaming in order to furnish the required quantity of dry steam through a given-sized outlet into the pan. The actual pressure in the pan will in any case be only a fraction of a pound, but dry steam reduces the rate of waterlogging and consequently favors penetration of steam into the soil. In general, four factors are to be considered in planning the equipment, namely, the capacity of the boiler, the pressure that can be maintained, the size of the steam outlet (pipe or hose), and the size of the pan. The efficiency of the outfit will depend upon its ability to supply a continuous flow of high-temperature steam to the pan at a sufficient rate to heat the enclosed soil to about 212° F. to the greatest depth in the shortest

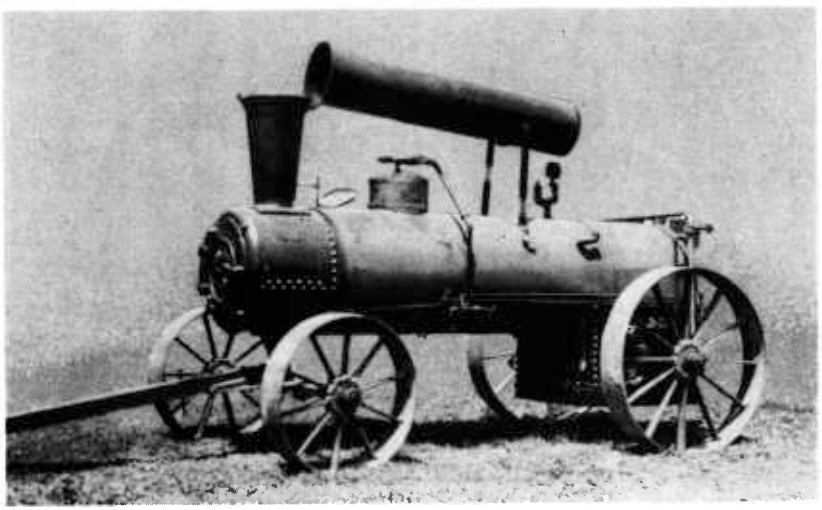

FIGURE 5.—Portable type of boiler adapted to the inverted-pan method of steaming.

possible length of time. Temperatures as low as 140° F. at greater depths will also have a sterilizing value. With a 40-horsepower boiler and a pressure maintained at 125 to 150 pounds together with a ¾-inch hose connection, it is possible to supply a pan as large as 100 square feet with the necessary steam for efficient sterilization.

The steaming pan is preferably made of no. 16 galvanized iron, reinforced with angle iron, although pans made largely of lumber may be used in some cases at a smaller initial cost. The size, shape, and construction of the pan may be made to suit the particular conditions at hand. The pan may ordinarily vary from 50 to 100 square feet in area, 6 by 12 feet by 8 to 10 inches in height being common dimensions, although pans 14 and 16 feet long and 6 feet wide are sometimes used. For loose, sandy soils, a pan 10 inches deep is preferable. Handles of iron pipe, or other devices for carrying, are ordinarily attached. Many operators are now suspending the pan under a pair of wheels with a lifting device which enables it to be raised

readily and moved by one or two men. (Fig. 6.) The lower edge of the pan should be sharp so that it may be pressed readily into the soil, thereby reducing the escape of steam at the point of contact with the soil. The inlet for the steam may be made through the top or side of the pan but should be so placed that the steam is not thrown directly into the soil. Usually some sort of perforated pipe or cap distributor for the steam is desirable on the inside of the pan. It is usually preferable to have the steam pan constructed by sheet-metal shops equipped for such work.

The steam may be led from the boiler to the pan by means of pipe or steam hose or both, depending upon the distance from the pan to the boiler. Usually the boiler can be moved to the side of the area to be steamed and a 25-foot 4-ply steam hose will be found to be sufficient and most convenient.

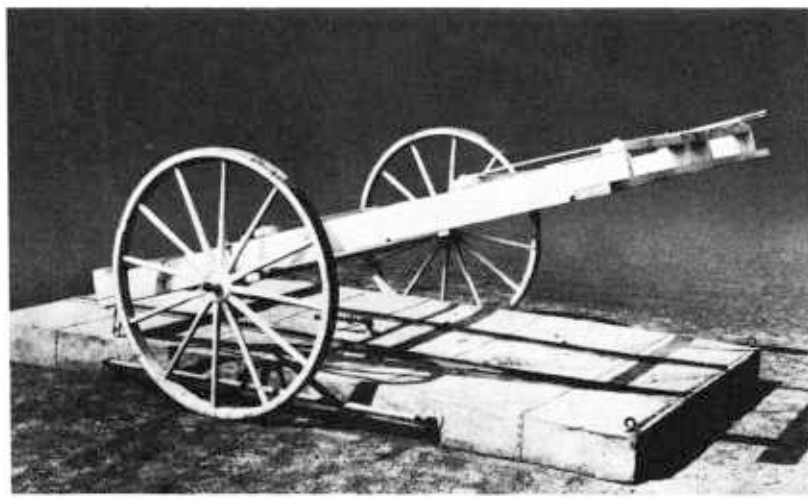

FIGURE 6.—Device for facilitating the moving of the steaming pans. The labor of soil sterilization may be reduced by hanging the heavy pan on a truck, as shown here, so that the pan can be easily moved and readily raised or lowered over the soil.

In addition to this equipment, growers in some sections prefer to carry sufficient heavy canvas or burlap to cover two or three pan areas of steamed soil after the removal of the pan, to conserve the heat in the soil for a longer period. It is even better to operate with two steaming pans, one of which is left in place on the freshly sterilized area to retain the heat while the other pan is used in steaming the next area.

### PREPARATION OF THE SOIL FOR STEAMING

Steaming is usually performed a short time before the seed is to be sown. In some respects, however, it is preferable to steam soil two to three weeks before sowing seed, since this permits of a partial or complete recovery of the soil from the effects injurious to seed germination and early plant growth. On the other hand, if the soil is steamed months before use, some of the beneficial effects may be lost unless special precautions are taken. On account of certain advan-

tages, fall steaming for spring seedbeds may often be a desirable practice.

In the northern tobacco-growing sections it is the usual practice to begin steaming in the spring as soon as the condition of the soil and the weather permit. This means that the frost must be out of the ground and the soil sufficiently dry to be properly worked and prepared for a seedbed. It is poor policy to work or steam soil that is too wet. Five times as much heat is required to raise the temperature of a pound of water a given number of degrees as is required for the same weight of soil. Furthermore, steam cannot penetrate readily through wet soil, and the distribution of heat becomes dependent upon conduction, with resulting lowered efficiency in the entire operation. It is also important that the soil should not be too dry when steamed, since weed seeds and parasites are less readily killed in a dry, dormant state. The soil also takes up water less readily after being heated in a dry condition. There is little or no danger of the soil being too dry in out-of-door seedbeds in the spring of the year.

Where glass-covered seedbeds are to be used, the preparation of the soil for steaming may be advanced in the spring and the soil maintained in a suitable condition by placing the frames and sash in position on the area to be steamed.

Any animal manures to be used, of course, should be applied and the soil put into condition for sowing or planting by spading or by plowing and disking before applying the steaming process. The object of this final preparation is to reduce to a minimum the danger of losing certain of the benefits derived from sterilization through subsequent contamination by working the soil after steaming. Commercial fertilizers free from tobacco material may be safely applied to the soil and worked in to a depth of 2 inches after sterilization. The seedbed areas should be properly located and slightly raised above the surrounding ground to reduce the danger of flooding from heavy rains. If the seedbed frames are not permanent, they should be placed around the steamed areas as soon as convenient to aid in preventing contamination of the soil by weed seeds and plant parasites from outside. Every precaution should be taken to prevent the transfer of parasites to the seedbed in soil or on equipment moved from farm to farm as, for example, on the wheels of steam tractors.

### FALL STEAMING

On account of the difficulty of performing the steaming sufficiently early in the spring during late or wet seasons, it seems advisable in many instances to resort to fall steaming. Most farmers would also find fall steaming preferable in that it would relieve the spring rush of work. While there are some disadvantages in fall steaming, particularly in the increased danger of recontamination of the soil with weed seeds and plant parasites, these may often be counterbalanced by several advantages. With a little additional care and expense, the danger of serious contamination of the soil may be partly prevented by choosing a desirable location for the beds and by protecting the soil with the frames and improvised covers of various sorts, such as old burlap or building paper.

The advantages of fall steaming naturally lie in reducing the rush of spring work and permitting earlier sowing than might otherwise be possible. There is considerable evidence that, on many soils, fall steaming well done and properly cared for will yield nearly as good results as spring steaming, even when the seed is sown at the same date. The preparation of the soil for fall steaming should be similar to that for spring steaming. Especial care should be taken, however, to prevent excessive flooding by locating the seedbeds desirably and providing adequate surrounding surface drainage. The soil should not be worked to any greater depth than necessary in preparing for sowing in the spring, loosening the soil to a depth of 3 or 4 inches usually being sufficient.

### TIME REQUIRED FOR STEAMING

The time required to sterilize the soil thoroughly by the steam-pan method and at the same time to get the maximum benefit in increased plant growth naturally varies to some extent with the type and condition of the soil as well as with the efficiency of the equipment. The time required for efficient sterilization varies especially with the porosity, heat conductivity, and moisture-holding capacity of the soil. The tendency in recent years has been to cut down the time of steaming to periods as short as 15 or 20 minutes, regardless of conditions, but this often has led to very unsatisfactory results. Under average conditions fully 30 minutes are required for best results, and under poor conditions 35 to 40 minutes may be necessary to sterilize the soil effectively. Under unusually good conditions 20 to 25 minutes may suffice, but it is not advisable to reduce the steaming period to this length of time unless a trial on the same soil in the previous season has shown it to be adequate. It is possible to reduce the required time somewhat by the use of two pans alternately, as previously suggested, hence eliminating the necessity of moving a pan immediately after shutting off the steam. It is also possible to retain some heat by covering the soil with heavy canvas or burlap after the removal of the pan.

In this connection it may be stated that soil may be unnecessarily injured by heating for an excessive length of time. This may happen particularly in greenhouse soils where steaming is sometimes continued for hours.

### TEMPERATURE

The temperature of the surface soil beneath the pan rises rapidly during steaming to approximately 210° to 212° F., the temperature of boiling water. As the steam comes in contact with the cool soil it rapidly condenses to water until the soil itself reaches the boiling temperature of water, when condensation is reduced to a minimum. If the surface inch or two becomes water-logged before reaching this temperature on account of steaming soils that are too wet at the start, the downward penetration of steam vapor is naturally interfered with, and the heating of the lower layers of soil becomes largely dependent upon heat conduction. Soil is a very poor conductor of heat, and as a consequence it requires considerable time to

heat layers of soil at a depth of 6 to 12 inches. On the other hand, the poor heat conductivity of soil reduces the rate of cooling after removal of the pan, and as a consequence considerable downward conduction of heat and sterilizing action may continue in the lower layers for several hours after the removal of the sterilizing pan. The rate of cooling is usually slowest at a depth of about 6 inches after 30 minutes of steaming. Sufficient heat may be maintained at this depth for 10 to 12 hours after steaming to have considerable sterilizing value. Sterilizing temperatures for soil steaming are ordinarily regarded as lying between 140° and 212°. These temperatures kill most weed seeds and soil organisms in a very few minutes, but the object of continued steaming is to secure these temperatures at as low a depth as possible.

## MANAGEMENT OF STEAM-STERILIZED SEEDBEDS

If the seedbed frames are not already in position during sterilization, they should be placed as soon as possible after steaming, to reduce the danger of blowing or washing of unsterilized soil into the steamed area. Care should also be taken not to walk on the sterilized soil or to introduce disease infection or weed seeds in any other way.. The soil should be prepared before steaming so as to require a minimum of working after steaming to prepare it for the seed.

The seedbed may be safely sown 12 hours after steaming, as far as soil temperature is concerned. Most soils are more or less toxic to seed germination and plant growth for some days after heating, and this injurious effect gradually diminishes as time elapses if the soil is in a moist condition. If the soil can be sterilized 1 or 2 weeks prior to sowing, therefore, a certain advantage is gained with respect to the rate of subsequent plant growth.

Since steamed soils usually dry out more rapidly and consequently may require more watering than unsteamed soils, it is well to give considerable attention to supplying water at the proper time in dry seasons when the seedlings are very young; otherwise small, tender seedlings like tobacco may be killed and the stand of plants in the seedbeds much reduced. This is particularly true with respect to glass-covered seedbeds and such beds as are sown with sprouted seed.

## COST OF STEAMING

The cost of sterilizing tobacco-bed soil by the steam-pan method naturally varies considerably with the particular circumstances under which it is performed. Growers who do not have a steam boiler must rely upon having a steaming performed by contractors who operate steaming outfits. The charges may be at a given rate per square foot, per pan, or at a flat daily or hourly rate, the grower generally furnishing the necessary fuel, which is usually computed at one-half ton of soft coal for 1,000 square feet of seedbed area. The cost of steaming may be expected to vary from $1 to $2 per hundred square feet. On account of the shortness of the season for sterilization of seedbeds and the possible occurrence of unfavorable weather conditions, the work is usually speeded up by operating 24 hours daily.

While the cost of steaming may appear relatively high in some instances, it is necessary to consider in this connection the saving in cost of weeding and the benefits that may accrue from the production of early, healthy, and vigorous plants for transplanting.

## SOIL STEAMING FOR CROPS OTHER THAN TOBACCO

The previous discussion has referred principally to the application of soil sterilization to tobacco culture. Manifestly, the same or similar methods may be applied to the production of other plant seedlings that are started in seedbeds and subsequently transplanted. The vegetable or truck gardener will, therefore, find the use of almost identical methods suitable for the production of the early, tender plants in particular, especially where seedbed diseases and weeds are abundant. Florists, nurserymen, and growers of special crops, such as ginseng, may also find the method adaptable to their problems. It is in the forcing of winter vegetables under glass, however, that soil sterilization has been most generally adopted. The culture of lettuce, radishes, tomatoes, and cucumbers in particular on a large scale under glasshouse conditions is accompanied by many difficulties not generally encountered in field crops. Since the soil is not exposed to the effects of winter and may be almost continuously under cultivation, it may become heavily infested with plant parasites of various kinds, especially nematodes and damping-off fungi. Soil sterilization by the steam method is the most practical remedy for these maladies, and in addition, the treatment generally hastens plant growth, this result being of especial value in vegetable culture under glass.

The special requirements for the applications of the steam-pan method of sterilization under forcing-house conditions will naturally suggest themselves. The use, wherever possible, of the steam boilers of the heating system is naturally a convenience in some respects, but where steam is carried for long distances through pipe, additional precautions may need to be taken to prevent the introduction of an excessive amount of water or wet steam into the pan. The size and shape of the pan should, of course, be such as to conform to the particular areas to be steamed. The duration of steaming usually should be increased for forcing-house soil above that recommended for seedbeds, the time required depending upon the type and condition of the soil and the parasite to be destroyed. In the case of nematode infestation, it is particularly important to sterilize the soil thoroughly to a considerable depth. A temperature of 140° F. or above for a few minutes is apparently required to kill nematodes. Since this pest may be harbored at considerable depth in the soil, it is advisable to attempt to secure such a temperature as deep as 8 to 12 inches. This may require as much as 1 hour of steaming under favorable conditions.

Certain objections present themselves with respect to soil sterilization by the steam-pan method in some greenhouses, since walls and pipes often interfere with covering all the soil with the pan. In such cases, a system of tile sterilization may prove most useful.

With this method, 4-inch tile lines are usually laid permanently 12 inches deep and 2½ or 3 feet apart. The steam is turned into the ends of the tile lines, from which it escapes into the soil. It is advisable for those who propose to use the tile system to obtain as much information as possible on the subject from other sources before proceeding with the details of the installation.

For the sterilization of small quantities of soil in the greenhouse, especially for the culture of seedlings in flats or for potting purposes, various types of inexpensive box soil sterilizers may be used. The usual box sterilizer has a removable end and the bottom is pitched so as to drain toward this end. Perforated steam pipes are laid on the bottom and the soil is then filled in to a depth of 1½ to 2 feet and covered. The steaming is complete when the surface soil reaches a temperature of 210° to 212° F.

Minor modifications of the various types of equipment to meet special requirements will naturally suggest themselves to those who are using or proposing to use the steam sterilization method.

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